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A new multistage construction chronology for the Great Serpent Mound, USA

Edward W. Herrmann [a,*], G. William Monaghan [b], William F. Romain [c], Timothy M. Schilling [d], Jarrod Burks [e], Karen L. Leone [f], Matthew P. Purtill [g], Alan C. Tonetti [h]

[a] Department of Geological Sciences, Indiana University, 1001 E. Tenth St., Bloomington, IN 47405, USA
[b] Indiana Geological Survey, Indiana University, Bloomington, IN, USA
[c] Newark Earthworks Center, Ohio State University, Newark, OH, USA
[d] Midwest Archeological Center, National Park Service, Lincoln, NE, USA
[e] Ohio Valley Archaeology, Inc., Columbus, OH, USA
[f] Gray & Pape, Inc., Cincinnati, OH, USA
[g] Department of Geology and Geography, West Virginia University, Morgantown, WV, USA
[h] ASC Group, Inc., Columbus, OH, USA

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ABSTRACT

Effigy mounds occur across the midcontinent of North America but their cultural purposes and construction chronologies are rarely known and often controversial. Determining the age and construction history of monuments is important to relate religious symbolism, scientific knowledge, and cultural continuity to groups within a region. Based mainly on circumstantial evidence, researchers have long held that Serpent Mound in Ohio, USA, was constructed 2000–3000 years ago during the Early Woodland (Adena) or Middle Woodland (Hopewell) periods. Excavations in 1991 recovered charcoal buried at shallow depths (35–45 cm) in fill units of the mound and the ^{14}C ages from two of these units indicated that Serpent Mound was built ~900 years ago, during the Late Prehistoric (Fort Ancient) period, much later than originally thought. Our recent multidisciplinary work provides a more complex, robust construction history of Serpent Mound. We used geophysics to map the mound, and solid-earth cores to provide accurate stratigraphy and organic samples for ^{14}C age estimates from the base of the mound. Bayesian statistical analyses of the seven ^{14}C ages from Serpent Mound suggest that it was first constructed ~2300 years ago during the Early Woodland (Adena) period but was renovated 1400 years later during the Late Prehistoric (Fort Ancient) period, probably to repair eroded portions of the mound. Modification of the mound is also indicated by a possible abandoned coil that is located near the head of the Serpent and visible only in the magnetometer survey.

1. Introduction

The Great Serpent Mound is one of the most iconic effigy mounds in the North American midcontinent (Fig. 1). Squier and Davis (1848: 96) described it as "probably the most extraordinary earthwork thus far discovered in the West." It has been designated as an Ohio State Memorial and a National Historic Landmark. In spite of these facts, relatively little modern archaeological work has been conducted within Serpent Mound or on the surrounding promontory. Our research seeks to define the construction chronology of Serpent Mound.

1.1. Previous work at Serpent Mound

Putnam (1890) conducted the earliest excavations at Serpent Mound. He placed trenches in the effigy and several nearby earthen mounds during 1887–1889, and later he led efforts to restore and preserve Serpent Mound. Putnam (1890) recognized that people of two different time periods occupied the Serpent Mound area and attributed the effigy to the earlier of these groups. Although the terms "Adena" and "Fort Ancient" had not yet been defined in the late 19th century, subsequent analyses of the artifacts recovered

* Corresponding author. Tel.: +1 812 856 0587.
E-mail address: edherrma@indiana.edu (E.W. Herrmann).

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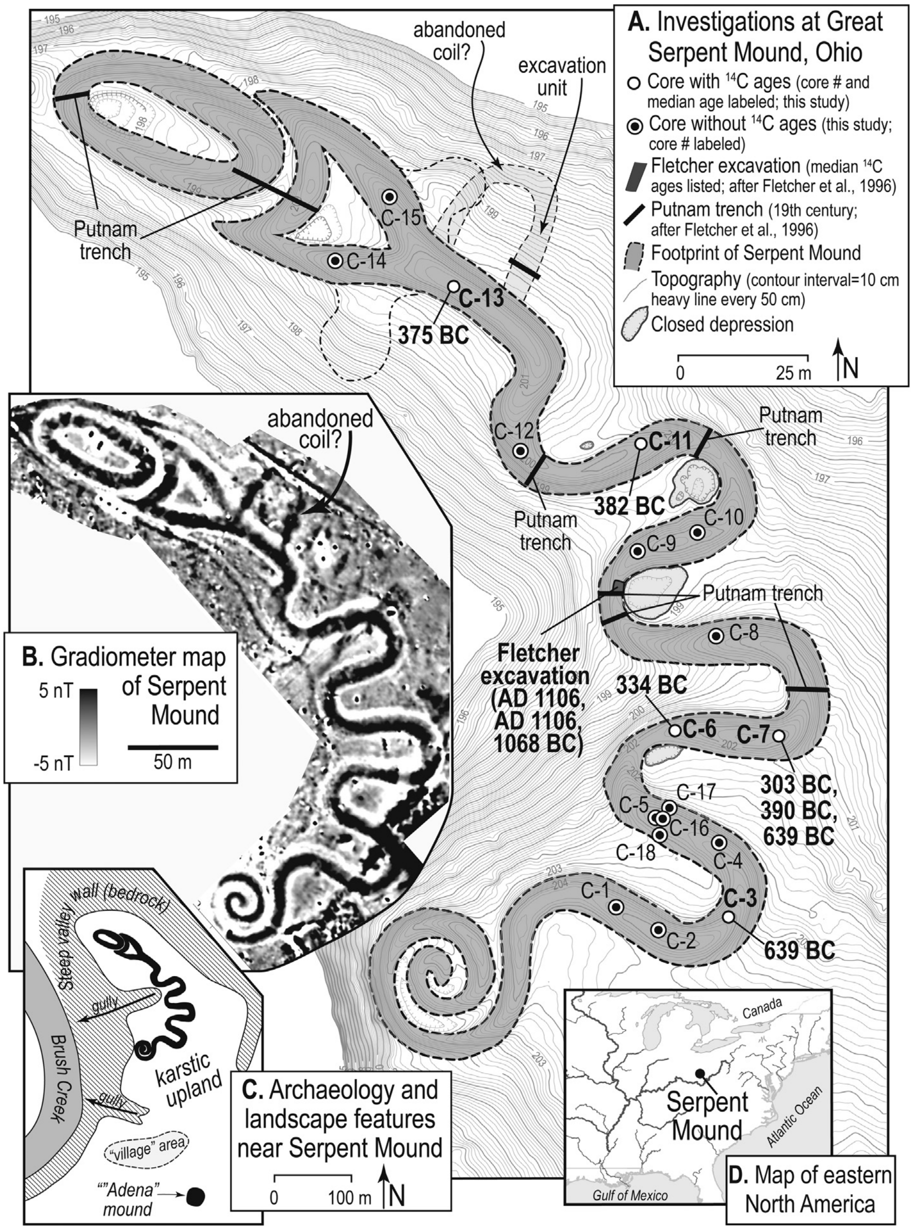

Fig. 1. Maps of the Great Serpent Mound, Ohio. (A) Base map showing topography near the top of the Serpent Mound ridge, the footprint of Serpent Mound, and the locations of cores and trenches placed into the mound. Contour interval 50 cm; core numbers labeled adjacent to core location; cores with ^{14}C ages labeled. See Table 1 for details of the ^{14}C samples. Note closed depressions near the ends of loops within middle part of Serpent. (B) Magnetometer map of Serpent Mound; image displayed at ±5 nT; readings < −5 nT displayed as −5 nT; readings >+5 nT displayed as +5 nT. Magnetometer data collected on a 12.5 × 50 cm grid; possible abandoned coil near the head of Serpent Mound labeled. Dark is positive. (C) Map of Serpent Mound site showing locations of adjacent mounds and prehistoric habitation areas, erosional gullies, and steep valley wall. (D) Map showing regional location of Great Serpent Mound, Ohio, within eastern North America. (Images provided courtesy of G. William Monaghan. Magnetometer map provided courtesy of Jarrod Burks.)

elsewhere within the site area are attributed most to either the Early Woodland Adena culture (ca. 500 BC–AD 200) or Late Prehistoric Fort Ancient culture (ca. AD 1000–1650) occupations (Abrams and Le Rouge, 2008; Clay, 2005; Cook, 2008), which suggests a long occupational history spanning >1500 years (Fletcher et al., 1996; Griffin, 1943).[1] Greenman (1934), Griffin (1943), Webb and Snow (1945: 341), and Webb and Baby (1957: 106) all believed that Serpent Mound was constructed during the Early Woodland Period, by people of the Adena culture.

The assessment of Serpent Mound as an Adena construction was circumstantial and based mainly on the Adena cultural affiliation of a conical mound about 200 m southeast of the Serpent (Fig. 1). First excavated by Putman (1890), the conical mound contained multiple burials and associated grave goods, including pottery and projectile points. These grave goods were later analyzed and assessed as Adena by Griffin (1943: 56–64), who also found both Adena and Fort Ancient materials in nearby cultural features. Even though Adena and Fort Ancient occupations both occurred near Serpent Mound, because Adena was the earliest well-documented occupation, its burials and artifacts were given precedence as temporal

[1] We recognize several taxonomic issues concerning the term "Adena" [Brown, 2005; Clay, 2005; Greber, 2005; Mainfort Jr., 2005]; however, for the purposes of this discussion and to maintain historic continuity, we will use "Adena" as a heuristic term of convenience.

indicators for when the mound was built. Griffin (1943: 57) concluded that: "Although artifacts taken by Putnam from the conical mound south of the serpent and from the lower level of the near-by village site cannot be positively assigned to the builders of the effigy, it is considerably less likely that the later Fort Ancient occupants built the serpent." This supposition remained the accepted construction age of Serpent Mound until 1996 when the first direct ^{14}C ages from within its fill were reported.

Fletcher et al. (1996) reopened one of Putman's trenches through the western end of a coil of Serpent Mound (Fig. 1). They documented the profile and collected charcoal from three contexts: two from mound fill just above what they considered the mound base and one from "natural sediment" below the mound base (Fletcher et al., 1996: 119, 132–133). ^{14}C age estimates from these contexts provided the first direct evidence for when Serpent Mound was built. The results indicated to Fletcher et al. (1996:133) that the mound was first constructed at 920 ± 70 BP (Table 1), which surprised most because these dates implied that the mound was built during the Late Prehistoric (Fort Ancient) Period, 1400 years later than originally suspected.

In 2011, we began a multidisciplinary project to reevaluate when and how Serpent Mound was built. Bayesian analysis of ^{14}C dates obtained during our work using an OxCal model suggests that Serpent Mound was first constructed soon after ca. 2300 years ago during the Early Woodland (Adena), as originally assumed. Despite the fact that these ages appear to contradict those provided by Fletcher et al. (1996), we believe that they are compatible and reveal a more complex construction and use history for Serpent Mound than previously thought.

2. Material and Methods

The characteristics and lateral continuity of the paleosol buried during mound construction are essential to resolve the chronology and construction sequence for Serpent Mound. Consequently, our methods focused on subsurface data collection at multiple locations in the mound. We combined magnetometer (gradiometer) survey, LiDAR data (1 m resolution) (OGRIP, n.d.) and data from a series of continuous, solid-earth cores, to construct a detailed stratigraphy and map of the mound and surrounding promontory. The methods employed were selected to minimize impact to the site, which was a requirement of our permission to work at the site, but still provide data capable of addressing our research questions.

The magnetometer survey (Geoscan Research FM 256 fluxgate gradiometer) provided images of near-surface anomalies, such as trenches, structural remains, and burned features. Magnetometer data were collected on a 12.5 × 50 cm grid, and processed through Geoplot 3.0; the resulting image is displayed at ±5 nT (Fig. 1), dark is positive (Burks, 2012). Magnetometer imaging revealed an arcuate-shaped anomaly near the neck of the effigy that is similar in size, shape and form to the existing coils in Serpent Mound (Fig. 1A, B). Because the anomaly has no surface expression, we excavated a 1 × 5 m trench across the anomaly revealing lithic debitage, fire-cracked rock and a projectile point fragment that may date to the Late Archaic period predating mound construction (Burks, 2012). Although no distinct features were present, the presence of light-colored silty sediment matched the location of the anomaly.

When coring, we avoided delicate areas of the mound (e.g., oval and tail) and previous excavation locales (Fig. 1), focusing instead on relatively thick portions of the mound. Although trench excavation would likely produce more detailed results, it is a much more destructive process. Small-diameter (3-cm) solid earth cores can provide similarly comprehensive and finely detailed mound stratigraphy and organic samples, but are far less invasive than trenching or other excavation techniques (Monaghan and Peebles, 2010; Stein, 1986).

Eighteen continuous solid-earth cores (Fig. 1) were collected using a Geoprobe (Model 54 TR) and dual tube sampling system, which drives continuous casing along with the sample tube to avoid core-hole collapse or sample contamination. These cores not only allowed us to directly determine the mound base and the thickness and character of the fill deposits at several places, but they also provided a spatially broader set of samples from which to determine the initial age of mound construction. Core depths varied from 120 to 280 cm and provided stratigraphically intact sediment samples from which the mound building sequence was interpreted. Core holes were grouted with bentonite upon completion. The cores were described for stratigraphic, pedogenic, weathering, and physical characteristics (color, texture, bedding, soil horizons, contacts, cultural or other inclusions, etc.). We particularly focused on the presence, depth and character of paleosols buried within or under the mound. The depositional properties and contacts between various mound fill units, and the pedogenic characteristics of the submound paleosol also provide important details concerning when and how the mound was constructed and provided important contexts for organic matter

Table 1
^{14}C ages from serpent mound.

Lab number	Core#	Depth (cm)	Material	^{14}C age (BP)	$^{13}C^{o}/_{oo}$	Median cal age[c,d]	2σ calibrated modeled age[d]
Context for OxCal model: ZOD/A$_b$ horizon (preconstruction)							
[a]Beta 337163	core 6	87–90	organic sediment	2170 ± 30	−22.2	334 BC	382–182 BC(360–116 BC)
[a]Beta 337168	core 7	105–110	organic sediment	2320 ± 30	−23.9	390 BC	414–257 BC(429–235 BC)
[a]Beta 337169	core 11	95–98	organic sediment	2310 ± 40	−23.2	382 BC	421–231 BC(482–209 BC)
[a]Beta 337170	core 13	100–105	organic sediment	2300 ± 50	−22.6	375 BC	419–228 BC(488–204 BC)
Context for Oxcal model: mound fill (postconstruction)							
[a]Beta 337162	core 3	75–80	organic sediment	2510 ± 30	−24.9	639 BC	790–540 BC(791–540 BC)
[a]Beta 337166	core 7	75–80	organic sediment	2530 ± 80	−23.8	639 BC	808–416 BC(808–416 BC)
[a]Beta 337167	core 7	85–90	organic sediment	2180 ± 30	−21.7	303 BC	362–173 BC(361–168 BC)
[b]Beta 55277	n.a.	35	oak/ash charcoal	920 ± 70	–	AD 1106	AD 998–1225(AD 997–1253)
[b]Beta 55278	n.a.	45	oak/ash charcoal	920 ± 70	–	AD 1106	AD 998–1225(AD 997–1253)
Context for Oxcal model: Submound (relationship uncertain)							
[b]Beta 47212	n.a.	132	oak charcoal	2920 ± 65	–	1068 BC	1261–907 BC(1368–925 BC)

[a] This study.
[b] As reported by Fletcher et al., 1996.
[c] Median calibrated age (calendar years) based on 2σ probability.
[d] Calibrated using OxCal 4.2.3; ages in parentheses are OxCal modeled ages (Bronk Ramsey, 2013) using IntCal13 atmospheric curve (Reimer et al., 2013); calibrated ages show entire 2σ probability range.

collected for AMS dating from mound fill and the submound A_b horizon of the paleosol that was buried during initial mound construction. We sampled all charcoal from the top of the buried paleosol because organic matter from the surface of buried soil horizons tend to be younger than those from deeper paleosol horizons (Matthews, 1985; Martin and Johnson, 1995:236; Wang et al., 1996:287). Collecting charcoal from such contexts is important because the youngest dates from the uppermost portion of a paleosol (i.e., A_b horizon) marks the age of the most recent charcoal deposited within the paleosol, which also represents the maximum age for when the surface was buried and cut off from additional organic matter inputs (Haas et al., 1986:473; Holliday, 1995:120; Holliday, 2001:90; Holliday, 2004:179).

The selected samples were submitted to BETA Analytic who treated them with an acid bath and dated the residue through AMS methods. Thus, even though our samples included much charcoal in the matrix, they were run as bulk sediment-type dates. The timing of construction of Serpent Mound was estimated using Bayesian statistics through OxCal 4.1 (Bronk Ramsey, 1994, 1995, 2001, 2008, 2009, 2013; Bronk Ramsey et al., 2010). The model was based on an analysis of the ages and contexts of the samples derived from the submound A_b horizon (i.e., Beta 337163, Beta 337168, Beta 337169, and Beta 337170; Fig. 2; Table 1).

3. Results

3.1. Serpent Mound Stratigraphy

Our interpretation of the Serpent Mound chronology is based primarily on the stratigraphic relationships between mound fill and the premound-construction ground surface, particularly by the presence of an intact soil profile upon which mound fill rests. Mound fill, which was normally ~1 m thick, was readily distinguishable from submound deposits in all cores (Fig. 3). Mound fill sediments are typically very fine sandy silt loams or silty clay loams with loose, subangular blocky structure. Small pebbles (<0.5 cm), charcoal flecking, fire-cracked rock and rootlets are typical inclusions, and abrupt, sharp contacts between different mound fill units are common. The surficial portion of the mound is typically disturbed, probably by historic plowing. However, the uppermost mound fill units in cores 5, 10, 11, 12 and 14, were compositionally different (sandier) with weaker pedogenic development compared to other cores and may indicate recent, probably historic, repairs to the mound (Fig. 3, core 11).

The deposits directly underlying Serpent Mound were generally silty clay loam that had weathered into a well-developed, 100–150-cm-thick A_b-E_b-Bt_b-C_{ox}/C_r soil horizon sequence. Typically, the A_b horizon of this paleosol is friable, dark brown (10 YR 3/3-3/2) silty clay loam and is usually underlain by an E_b horizon composed of powdery, very friable silt loam (10 YR 7/2-7/3). The E_b horizon is underlain by a dense silty clay B_t horizon (7.5 YR 4/6) that is in turn underlain by weathered bedrock (C_r horizon) or dense, oxidized loess (C_{ox} horizon). Overall, the characteristics of this paleosol, such as well-developed E and B_t horizons, suggest that it underwent a relatively long period of pedogenesis, and represents the ground surface buried during mound construction. The characteristics of the buried A_b horizon (i.e., color, organic-matter content, structure, etc.) and its position within the underlying sequence of soil horizons clearly distinguish it from overlying mound fill deposits.

Although it represents the ground surface upon which the Serpent Mound was constructed, the surface of the A_b horizon of the submound paleosol is occasionally disturbed, probably during the construction process, and sometimes mixed with the underlying E_b horizon in cores 3, 5, 7, 10, 11, and 12. These zones of disturbance (ZOD) occur only in the upper several cm of the paleosol (e.g., A_b and E_b horizons) and included some charcoal flecking and occasional fragments of fire-cracked quartzite (i.e., cores 7 and 12). No charcoal or organic matter was observed beneath the buried A_b horizon from our cores, but was noted by Fletcher et al. (1996:119). We believe that the ZOD was created as a result of mound-building processes during the initial construction of Serpent Mound.

3.2. Radiocarbon dating and OxCal chronological model

To estimate when Serpent Mound was first constructed, charcoal or charcoal-rich sediments were sampled from near the base of the mound. These samples were derived from the top of the submound paleosol (ZOD/A_b horizon) and from fill just above the base of the mound and provided seven ^{14}C ages from five different cores (e.g., Cores 3, 6, 7, 11, 13; Figs. 1 and 3; Table 1). The charcoal pieces sampled were too small or degraded for taxonomic identification beyond noting them as carbonized plant materials and most were too small to remove from the matrix or to submit as standalone dates. Notably, the locations for the five cores from which ^{14}C ages were obtained are from widely separated areas of the mound. Four of these ages derive from the ZOD (Cores 7 and 11; Figs. 1 and 3; Table 1) or A_b horizon (Cores 6, and 13; Figs. 1 and 3; Table 1) that marks the base of the mound and the three others were from emplaced mound fill directly above the base of the mound (Cores 3 and 7; Figs. 1 and 3; Table 1).

The ^{14}C ages were calibrated used OXCAL 4.1 and their calibrated probability ages range from 639 to 303 BC (combined 95% probability range of 808–116 BC; Table 1; Fig. 2). While this is up to a ~400 year spread, the range is small compared to ~1400 years

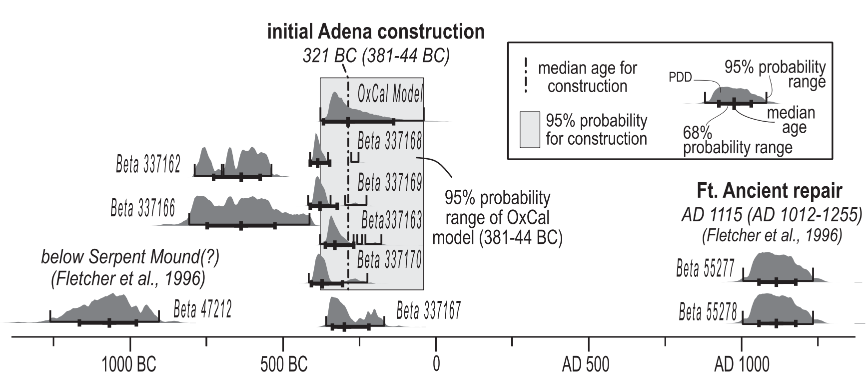

Fig. 2. Diagram showing construction chronology for Great Serpent Mound. Results and interpretation of OxCal model are shown as well as the distribution and probability density diagram (PDD) of individual calibrated ^{14}C ages of all samples reported from Serpent Mound; ages shown are OxCal modeled ages (Bronk Ramsey, 2013) using IntCal13 atmospheric curve (Reimer et al., 2013). See Table 1 for details of the ^{14}C sample and unmodeled calibration results. (Images provided courtesy of G. William Monaghan.)

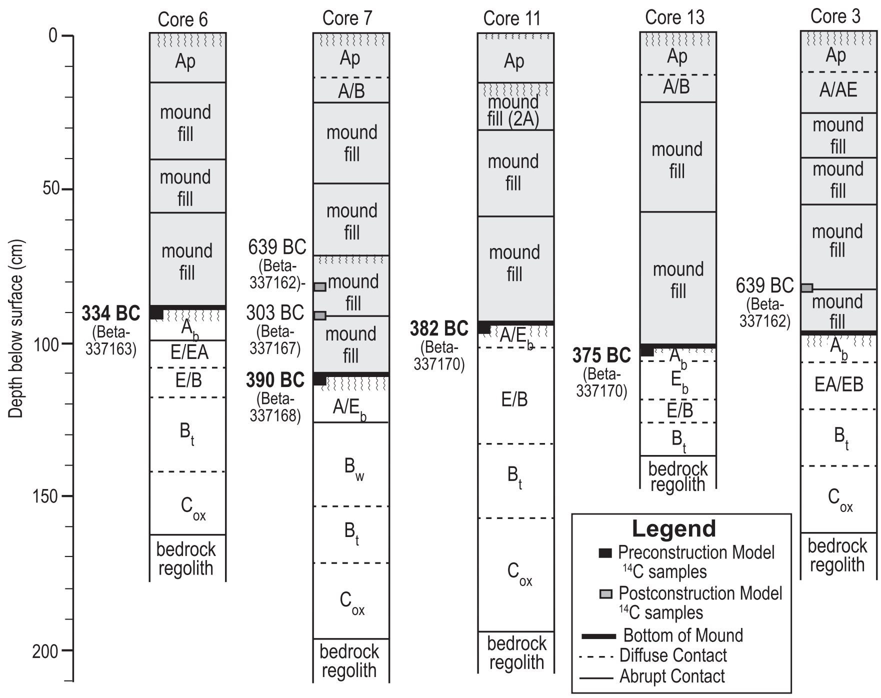

Fig. 3. Diagram showing sediment profile logs of dated cores; core numbers labeled above logs; locations of cores shown in Fig. 1. ^{14}C sample depths in core marked and calibrated ages labeled; see Table 1 for details of the ^{14}C samples and calibration results. Mound fill sediments are indicated by light gray; bottom of mound indicated by thick black line. The submound paleosol was clear in all cores and is located beneath the thick black line; soil horizons labeled in the core logs. Mound fill units are separated by clear, abrupt contacts between units.

separating our youngest age and that suggested by Fletcher et al. (1996) for the construction of Serpent Mound (i.e., 303 BC and AD 1106, respectively; Fig. 2; Table 1). The range of our dates is even tighter if the ages derived from the emplaced mound fills, especially Beta 337162 and Beta 337166, which occur 15–25 cm above the mound base and are 200–300 years older than those from ZOD/A (Table 1), are discounted. This age discrepancy may have resulted because charcoal deposited in submound A_b horizons or preconstruction cultural features were incorporated into fill when the mound was first built. The older dates likely represent charcoal from deeper, older horizons that were borrowed from their original context in order to be placed on the mound, which has also been noted at other mound locales (Saunders et al., 2005; Monaghan and Peebles, 2010; Black, 1967).

The initial construction chronology of Serpent Mound was modeled through OxCal as a single-phase event that occurred very rapidly (i.e., within several years). The model was constructed to yield the maximum possible age for burial of the submound paleosol. The results indicate that the paleosol was buried sometime after 321 BC (95% probability range of 381–44 BC; Fig. 2), which also represents the earliest possible time of mound construction.

4. Discussion

4.1. Initial construction

Although the OxCal model provides a maximum construction age, we believe that taken as a whole our data strongly support that Serpent Mound was first constructed ~2300 years ago, rather than ~1400 years later. Our results indicate the presence of a preconstruction paleosol beneath Serpent Mound, and that charcoal from different locales along its surface dates consistently to ~300 BC. The youngest calibrated age within the 95% probability range is 116 BC and we obtained no dates associated with the later Fort Ancient occupation of the site. However, the basic problem is that the age of the charcoal in paleosol A_b reflects timing of the event through which it was deposited and is not necessarily associated with the burial of the paleosol. Consequently the mound could have been constructed any time after 300 BC. The precision of the model and exactly when the paleosol was buried is complicated by sample genesis and contexts. Unlike the construction ages reported from other mounds using similar techniques (e.g., Monaghan and Peebles, 2010; Monaghan et al., 2013), the estimate for when Serpent Mound was built, including that of Fletcher et al. (1996), is based on detrital charcoal which can impart additional errors.

The disturbance of the premound A_b horizon that formed the ZOD likely occurred when Serpent Mound was built; however, the charcoal fragments within it were not necessarily deposited when the ZOD was formed. They were likely deposited in the soil during earlier, preconstruction natural and cultural events and their residence time in the soil (i.e., the time lag between when charcoal was first deposited in the paleosol and subsequently buried and preserved with the paleosol during the initial mound construction) is unknown. The uncertain soil residence time of the charcoal is further complicated because it could be derived from heart- or sapwood. If from heartwood, the tree could be a few hundred years older than the event during which it was burned and deposited. Given the ~1400 year difference between an Early Woodland (Adena) and Late Prehistoric (Fort Ancient) construction, the discrepancy of a few hundred years related to relic wood is not a serious impediment to resolving when Serpent Mound was first built.

Our approach to resolving when Serpent Mound was first built is similar to that commonly used to date paleosols, which assumes that the time of paleosol burial is approximated by the youngest ages found (Haas et al., 1986:473; Holliday, 1995:120; Holliday, 2001:90; Holliday, 2004:179; Martin and Johnson, 1995:236). Saunders et al. (2005:636–637) followed a similar process to

determine when mounds were first constructed at Watson Brake. They used bulk sediment (humate) and charcoal from submound paleosols to establish when the soil was buried (i.e., the earliest age for mound construction). This initial construction age was then further constrained by the ^{14}C ages of overlying mound-use layers. For example, the submound paleosol from Mound A dated to 3515 BC while the first overlying use surface dated to 3345 BC. A similar few hundred year difference generally occurs between submound paleosol ages and those of mound surfaces, which range 3500–3950 BC and 3263–3710 BC, respectively (Saunders et al., 2005:640–642), and supports the contention that the youngest ages of a paleosol closely corresponds with its burial, as suggested by several other studies (Holliday, 2004:182; Holliday, 1995:120; Martin and Johnson, 1995:236; Haas et al., 1986:473).

Studies of charcoal from modern soils also support the contention that the youngest ages from the paleosol are generally the best approximate of the time of burial (Payette et al., 2012; Sanborn et al., 2006). Payette et al. (2012) and Sandborn et al. (2006) collected charcoal from the A-horizon and sub-A-horizon of forest soils in Quebec and British Columbia (respectively) to document the timing of fires. They showed that the youngest charcoal occurred in the A-horizon, the majority of which is < 400 years old, and that older charcoal was more common at depth in the soil profile. Studies focused on black carbon (including charcoal) turnover rates confirm that surficial soil horizons up to 20 cm deep are dominated by younger, fast-cycling charcoal with turnover rates of about 300 years (Hammes et al., 2008; Fontaine et al., 2007). Such a distribution of charcoal in the soil profile (young in surface soil horizons and older charcoal preserved at depth) has been noted and discussed by others (e.g., Matthews, 1985; Martin and Johnson, 1995:236; Wang et al., 1996:287). The concentration of younger charcoal in A-horizons results because high rates of biological activity, turbation and accelerated leaching can promote rapid oxidation and accelerate organic debris destruction. Although charcoal that is thousands of years old can be preserved in the upper portion of an A horizon, it is not common. For example, Payette et al. (2012:9,10) found that although charcoal in the modern A-horizon ranged from modern to 1750 BP, the mode of all ages (145 BP) was skewed very young and more in line with a contemporary age. If this soil were buried today, most of the charcoal would date to within a few hundred years of present. Similarly, if the submound paleosol at Serpent Mound were buried during a Fort Ancient construction, the ages of its A horizon should be concentrated during a few-hundred-year interval before AD 1100. The distribution of ages (Fig. 2) strongly suggests that the submound paleosol was more likely buried during an Adena construction.

Such a conclusion is warranted because all of the (95% probability) calibrated age ranges reported from any context within Serpent Mound, except for those recorded by Fletcher et al. (1996), were older than 116 BC (Fig. 2; Table 1). If Serpent Mound was first constructed after AD 1100, as suggested by Fletcher et al. (1996), then the presence of 900 year old organic matter would be expected on the surface of the paleosol. Because of the lack of any younger charcoal, a more acceptable explanation for the age of submound charcoal is that it approximates when the paleosol was buried and the initial mound construction ~2300 years ago (Fig. 2).

4.2. Multi-stage construction

An initial Fort Ancient construction of Serpent Mound proposed by Fletcher et al. (1996) is contradictory with our OxCal construction model and ^{14}C age ranges (Fig. 2; Table 1). Our data suggest that the mound was first built ~1400 years earlier and contemporary with an Adena occupation as presumed throughout most of the 20th century. Such an ostensibly substantial temporal incompatibility could be resolved by suggesting that Fort Ancient-age charcoal was introduced into the mound historically during Putman's excavations or his subsequent mound restoration—an assumption that is not necessarily warranted. Although historic repair may be indicated by our core data and the Fletcher et al. (2006:122) excavation, the historic repair is stratigraphically higher in the mound fill units than the samples Fletcher et al. obtained for dating.

The evidence compiled by Fletcher et al. (1996) concerning the reliability of their ^{14}C ages is generally convincing and supports the charcoal as authentically related to a Fort Ancient (re)construction episode 900 years ago, which leaves the contradiction between the two initial construction chronologies unresolved. To settle this contradiction, we propose that Serpent Mound was constructed and then later modified during two distinct episodes: an Adena construction ~2300 years ago during which the mound was first built, followed ~1400 years later by an episode of Fort Ancient renovation or repair. Lynott (2007:558) found evidence of a similar repair episode at the Hopeton Earthworks where prehistoric groups likely renovated the Hopewell age monument some 56 km northwest of Serpent Mound 800 years after its construction. The reason for renovating Serpent Mound 900 years ago is unknown, but might relate to repairs necessary after parts of the mound were damaged as a result of erosion, sinkhole subsidence, or both. Damage to some of the mound extensive enough to require repairs is not surprising given its low pre-restoration height (generally $\leq$1 m high), antiquity of initial construction, ridge-top landscape position, and associated karst topography (Figs. 1, 2 and 4).

Several lines of evidence support multiple episodes of construction for Serpent Mound. The set of dates obtained by Fletcher et al. (1996) and our set of dates are each internally consistent, albeit separated by 1400 years, but are also from different contexts. These factors imply that they may mark two distinct construction events within different parts of the mound (Fig. 2; Table 1). Except for the two AD 1106 dates reported by Fletcher et al. (1996) (Table 1), all ^{14}C ages reported from Serpent Mound predate ~300 BC, which further demonstrates that an initial mound construction during the Fort Ancient period is implausible. We recovered no Fort Ancient age organic matter from the mound base anywhere along the extent of the mound (Fig. 1). In fact, all the ages from the base of the mound, which were spread along most of the length of the mound, were at least 1400 years older and are remarkably similar to each other (Figs. 1 and 2). Even the exceptions to these ages (Beta 337162 and Beta 337166; Fig. 2; Table 1) are older, not younger, than the model median age of 321 BC. The absence of charcoal younger than ~300 BC is strong evidence that Serpent Mound was constructed during the Early Woodland (Adena) Period (Fig. 2).

Fort Ancient-age charcoal occurs only in the Fletcher trench (Figs. 1 and 4), and their contexts are atypical compared to those from other locales. For example, cores show that a well-developed, generally continuous paleosol underlies most of Serpent Mound but is absent in the Fletcher trench (Fletcher et al., 1996: 121–122) (Fig. 1). Coring and LiDAR data also show the mound is typically ~100 cm thick and directly underlain by a ZOD, which incorporated the premound A_b horizon during mound construction (Figs. 1 and 4). Where the Fletcher trench was placed, at the western end of coil 4, however, is different. Not only is the submound paleosol absent here, the mound is only ~50 cm thick, and blocks downslope drainage from the edge of a surface depression (Fig. 4). This depression and that within coil 5 (Figs. 1 and 4) form the head of an erosional gully that drains the Serpent Mound promontory. Considering that karst and sinkholes are common across the landform, the depressions may be active sinkholes (Figs. 1A and 3B). Erosion was likely where coils of Serpent Mound block the

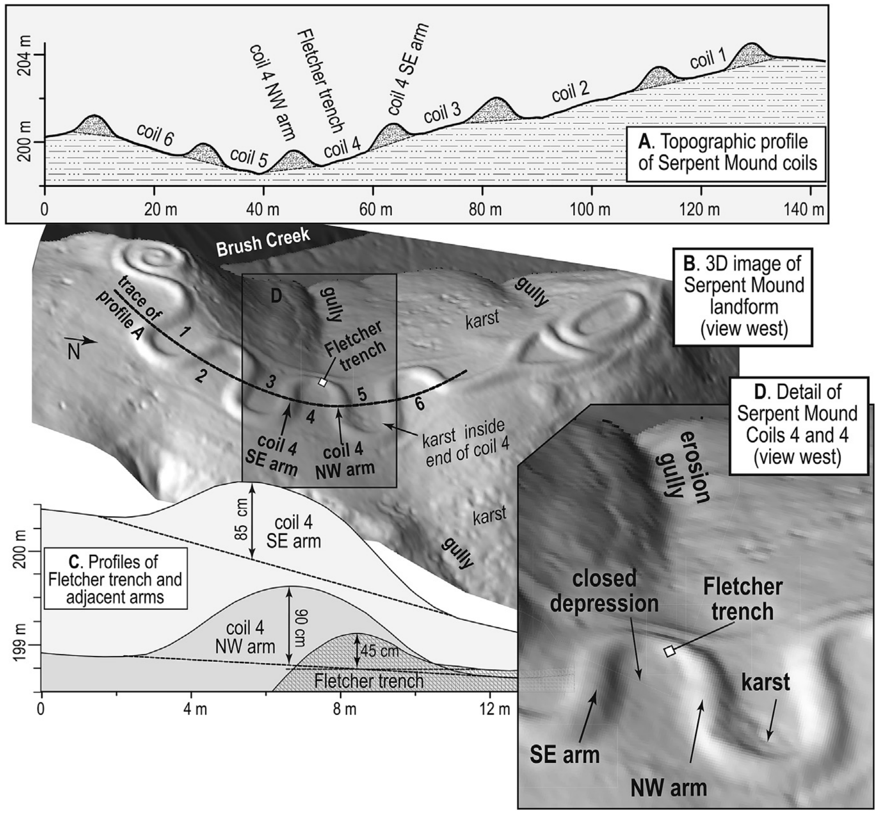

Fig. 4. Three-dimensional (3D) relief maps and topographic profiles for Great Serpent Mound, based on LiDAR data (OGRIP, n.d.). (A) Topographic profile through major body coils of Serpent Mound; view generally east and northeast. Location of profile shown in B. Profiles based on LiDAR contours maps (Fig. 1). Positions of coil arms and Fletcher trench labeled. (B) 3D relief map of Serpent Mound showing position of Serpent Mound in the uplands and erosional gullies on east and west side of mound; gullies drain into a deeply incised (~70 m) Brush Creek valley that developed on Silurian carbonates (Reidel, 1975). Small depressions surrounding the mound are probably karst (sinkhole) features. Depressions inside the ends of coils 4 and 5 may represent active sinkholes (see Fig. 1). Location of trace for profile A shown; coils, coil arms, and trench locations discussed in text are labeled. (C) Three topographic profiles showing Fletcher/Putnam trenches at the western end of coil 4 and the adjacent SE and NW arms of coil 4 of Serpent Mound. Thickness of mound fill shown; base and thickness of Fletcher trench after Fletcher et al. (1996); base and thickness of adjacent coils based on Cores 8, 9, and 10 and the LiDAR morphology of Serpent Mound. (D) 3D relief map of Serpent Mound showing details of coils 4 and 5; Location of image shown by shaded area in panel B. Note karst and closed depressions occur at the ends of the coils. (Images provided courtesy of G. William Monaghan.)

natural drainage through gullies (e.g., west end of coil 4 where the Fletcher trench was placed; Figs. 1A and 3C) and would have been particularly extensive where the drainage was headed by a sinkhole (Fig. 4B). When these sinkholes were active, they would have promoted mound instability and erosion through submound drainage or collapse.

Because of its landscape position within an upland drainage gully and adjacent to a possible sinkhole, the area of the Fletcher trench has probably long been prone to intermittent erosion that was likely extensive enough to require periodic repairs. Erosion and redeposition within this part of the mound are supported by the age of charcoal buried 70 cm below the Fort Ancient mound fill in the Fletcher trench. The depth and age of this material (2920 BP, 95% probability range 1368–925 BC, BETA 47212; Table 1) led Fletcher et al. (1996: 132–133) to suggest that it was related to an earlier Late Archaic occupation and was “carried to the lower depth by bioturbation or some other mode of transport.” We agree but suggest that the “other mode of transport” was likely long-term processes associated with gulley formation (Fig. 4). Given the age of the buried charcoal, gully formation was ongoing during the Early Woodland. Whether the erosion and redeposition occurred before or after the initial mound construction is uncertain, but the lack of submound A_b/E_b horizons in the Fletcher trench is consistent with erosion extensive enough to completely remove the original (Adena) mound fill and the upper part of the paleosol. The remaining coil arms (e.g., coil 4, Fig. 4) that parallel the erosional gully were apparently not significantly altered by erosion.

Other Serpent Mound alterations, however, may have occurred at the site prehistorically. A possible reconfiguration of Serpent Mound, which may mark an erased coil, was identified as a sinusoidal-shaped magnetic anomaly at the neck of the Serpent (Fig. 1A, B) (Burks, 2012). Because of its similar size and geometry to the other Serpent Mound coils and lack of surface expression, the anomaly is believed to be an abandoned and erased coil. Lithic debitage, fire-cracked rock, and projectile point fragments, one of which may date to the Late Archaic Period, were recovered from a trench excavated through the eastern arm of the anomaly (Fig. 1) (Burks, 2012). Even though none of the artifacts were associated with apparent features, the presence of Late Archaic cultural materials within the footprint of the erased coil suggests that it may have been constructed upon a Late Archaic occupation horizon or that these artifacts were incorporated into the base of the mound during construction. However, no direct evidence of mound construction was noted within the trench, which is not surprising given that evidence of mound construction was also lacking below the ZOD/A_b horizon in cores or trenches within the mound. Moreover, the extensive historic disturbances around Serpent Mound, especially 19th-century land clearance, plowing, and erosion and post-Putnam historic renovation, pathways, etc., would have also significantly affected the upper 20–30 cm of the ground surface. If

this anomaly is an abandoned coil, other chronological and morphological data may shed light on the timing of its erasure and possible mound reconfiguration. For example, the age of the pre-mound paleosol in Core 13 (419–228 BC, BETA 337170; Table 1), which lies adjacent to the abandoned coil (C-13; Fig. 1A), is consistent with other dates reported for the base of the mound. The consistency of this age with those from across the mound suggests that the abandoned coil may have been built earlier and erased during the initial construction of Serpent Mound. If so, the erasure of the coil may have marked an early Adena design change that reconfigured Serpent Mound to create new or expanded cultural symbolism.

5. Conclusions

By integrating previously reported absolute ages (e.g., Fletcher et al., 1996) and archaeological interpretations (e.g., Griffin, 1943) with new ^{14}C ages from the base of the mound (Table 1), we have reassessed the construction age of Serpent Mound. This integration provides a more complete and realistic resolution to the mound's construction chronology and suggests a more complex history for the mound. The similarity and consistency of ages within the ZOD/A_b (Fig.3; Table 1), their broad distribution along the extent of the mound (Fig. 1), and a complete lack of post-Adena charcoal in the ZOD/A_b provide the strongest evidence for when the submound paleosol was buried and Serpent Mound construction began. Serpent Mound was initially constructed 2300 years ago during the Early Woodland (Adena) Period, but was then modified, repaired, or renewed ~1400 years later during the Late Prehistoric (Fort Ancient) Period. Whether the mound was in continuous use during the 1400 years between its initial construction and subsequent repair is not clear from these data. However, a possible erased coil near the head of the serpent indicates that other alterations, potentially several hundred years earlier than the Fort Ancient repairs, may also have occurred. This suggests a deeper, richer, and far more complex history for Serpent Mound than previously known.

Renovating or reuse of cultural monuments is not unusual worldwide and often occurs when a new culture enters a region. However, another interpretation of the integrated data from Serpent Mound suggests that it was regularly used, repaired, and possibly reconfigured by local groups for more than 2000 years, which may imply at least some level of long-term cultural continuity in the use of this iconic monument. Whether cultural continuity predominated at Great Serpent Mound is unknown, but should be a focus for new research in the region.

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